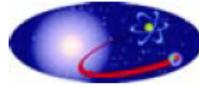




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# The MAJORANA DEMONSTRATOR for $0\nu\beta\beta$ : Current Status and Future Plans

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on behalf of the MAJORANA COLLABORATION



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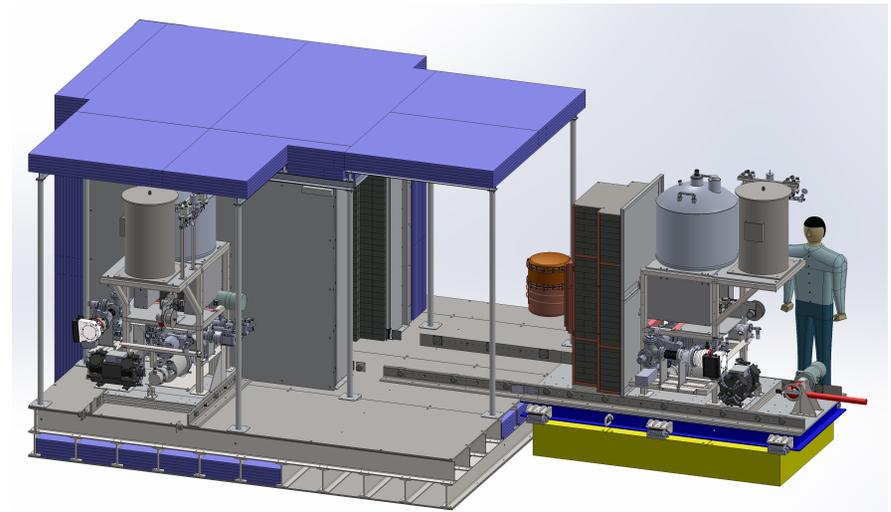
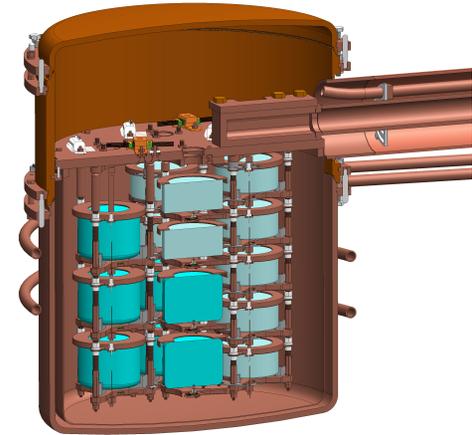
THE UNIVERSITY of  
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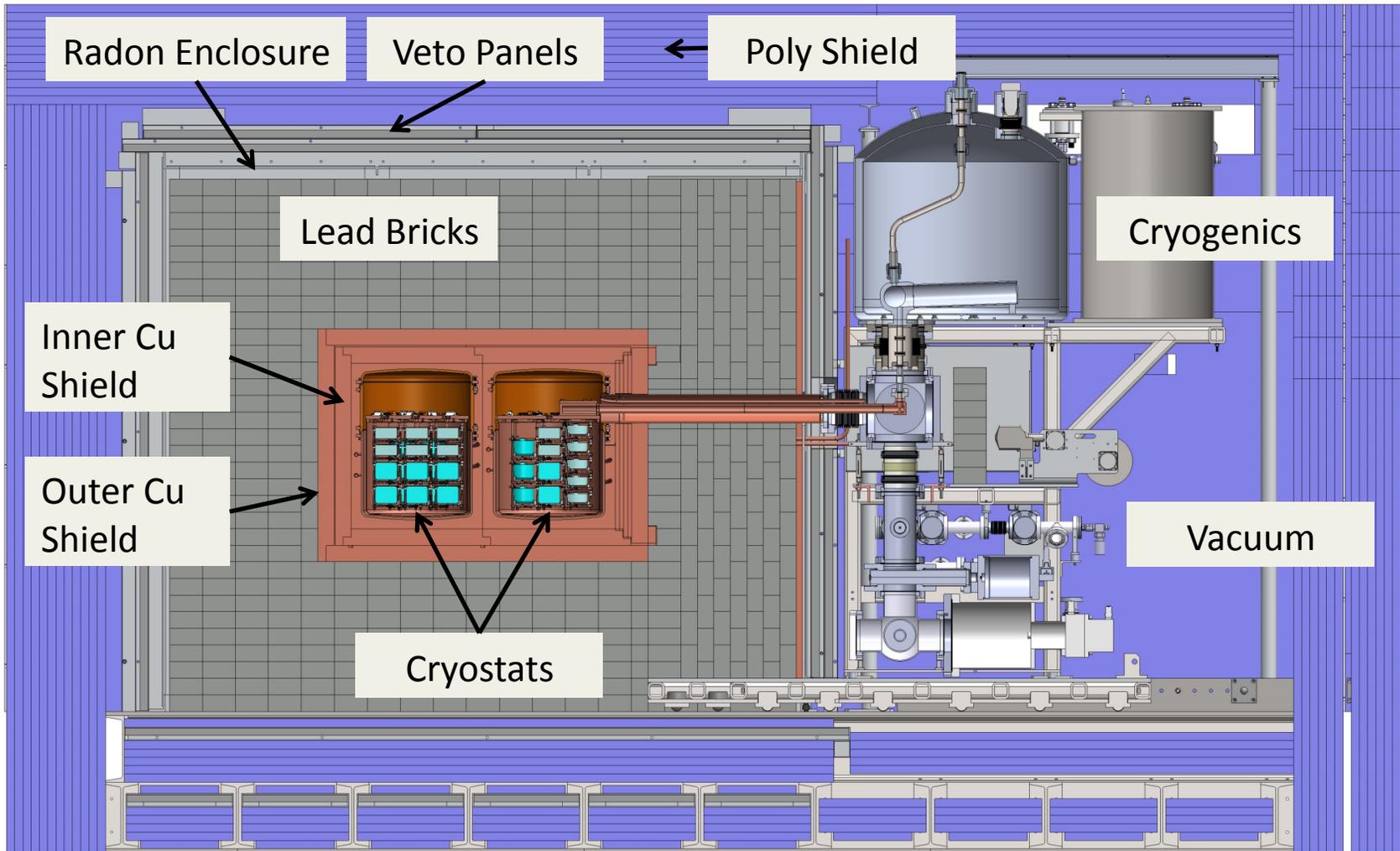
# The MAJORANA DEMONSTRATOR



- Goals:
  - Demonstrate backgrounds low enough to justify tonne-scale experiment construction
  - Establish feasibility of modular Ge detector array construction and deployment
  - Test the Klapdor-Kleingrothaus observation claim
  - Search for additional physics beyond the Standard Model
- Background goal in  $0\nu\beta\beta$  ROI (4keV @2039keV):
  - 3 counts/ROI/tonne/year (after cuts)
  - scales to 1 count/ROI/tonne/year for a tonne-scale experiment
- Located underground at 4850' Sanford Underground Research Facility
- 40kg of Ge detectors:
  - 30kg of 86%  $^{76}\text{Ge}$
  - 10kg of  $^{\text{nat}}\text{Ge}$
  - P-type Point-Contact
- 2 independent cryostats
  - ultra-clean electroformed copper
  - 20kg detectors per cryostat
  - naturally scalable
- Compact shield
  - Passive Cu, Pb, Poly shield, active muon veto



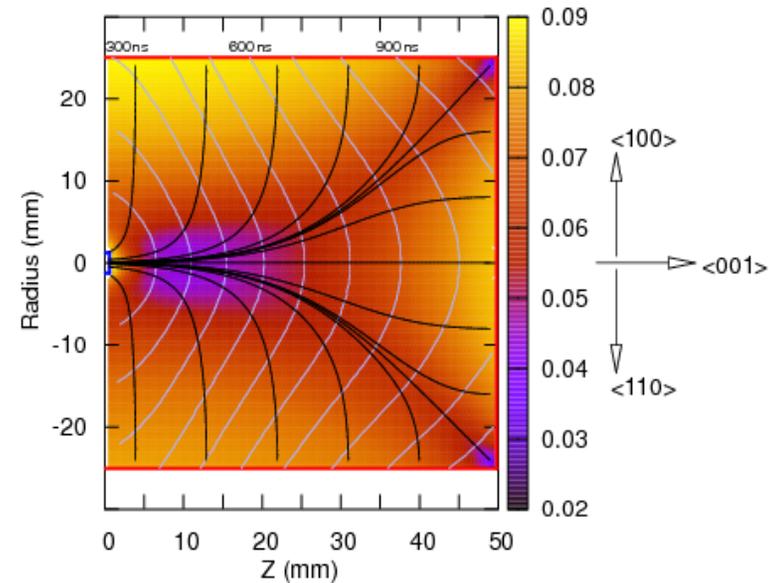
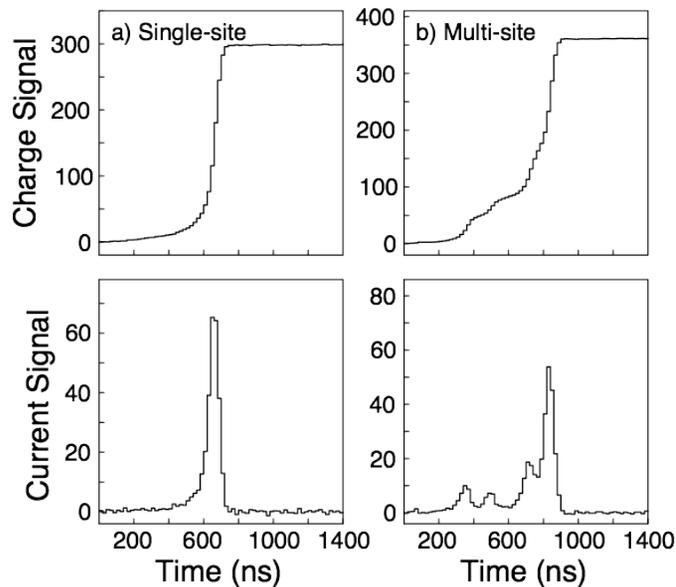
# The MAJORANA DEMONSTRATOR



# Point Contact Detectors (PPCs)



- No deep hole; small point-like central contact
- Length is shorter than standard coaxial detector
- Simple, cost-effective, low-background
- Localized weighting potential give excellent multi-site rejection, required for  $0\nu\beta\beta$
- Low capacitance ( $\sim 1\text{pF}$ ) gives superb resolution at low energies, low threshold
  - Allows effective rejection of  $^{68}\text{Ga}$  through tagging of  $^{68}\text{Ge}$  x-rays
  - Enables extensive low-energy physics program

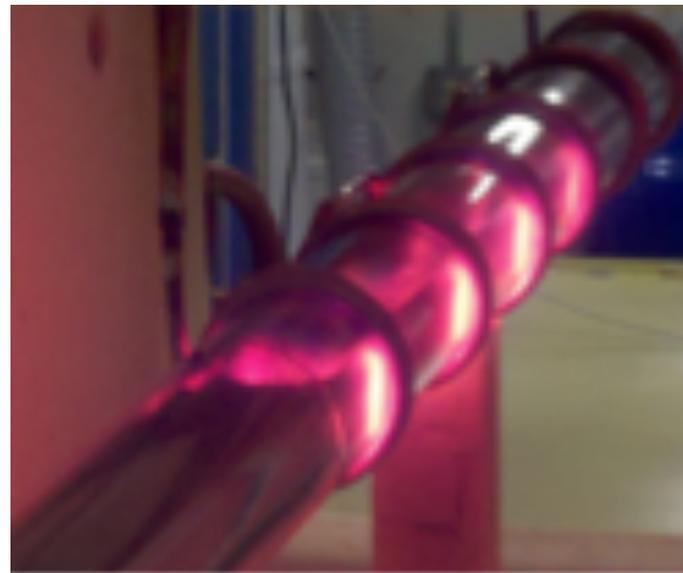


Luke et al., *IEEE trans. Nucl. Sci.* 36 , 926(1989); P. S. Barbeau, J. I. Collar, and O. Tench, *J. Cosm. Astro. Phys.* 0709 (2007).

# Producing <sup>enr</sup>Ge Detectors



- 42.5kg <sup>enr</sup>Ge (60.5kg GeO<sub>2</sub>) produced at ECP, Zelenogorsk, Krasnoyarsk, Russia.
- Transported shielded by sea, 2 shipments
- Reduction and Refinement: ESI, Oak Ridge, TN
- Detector fabrication: Ortec, Oak Ridge, TN
- Hand-transported to SURF
- First 10 enriched detectors underground

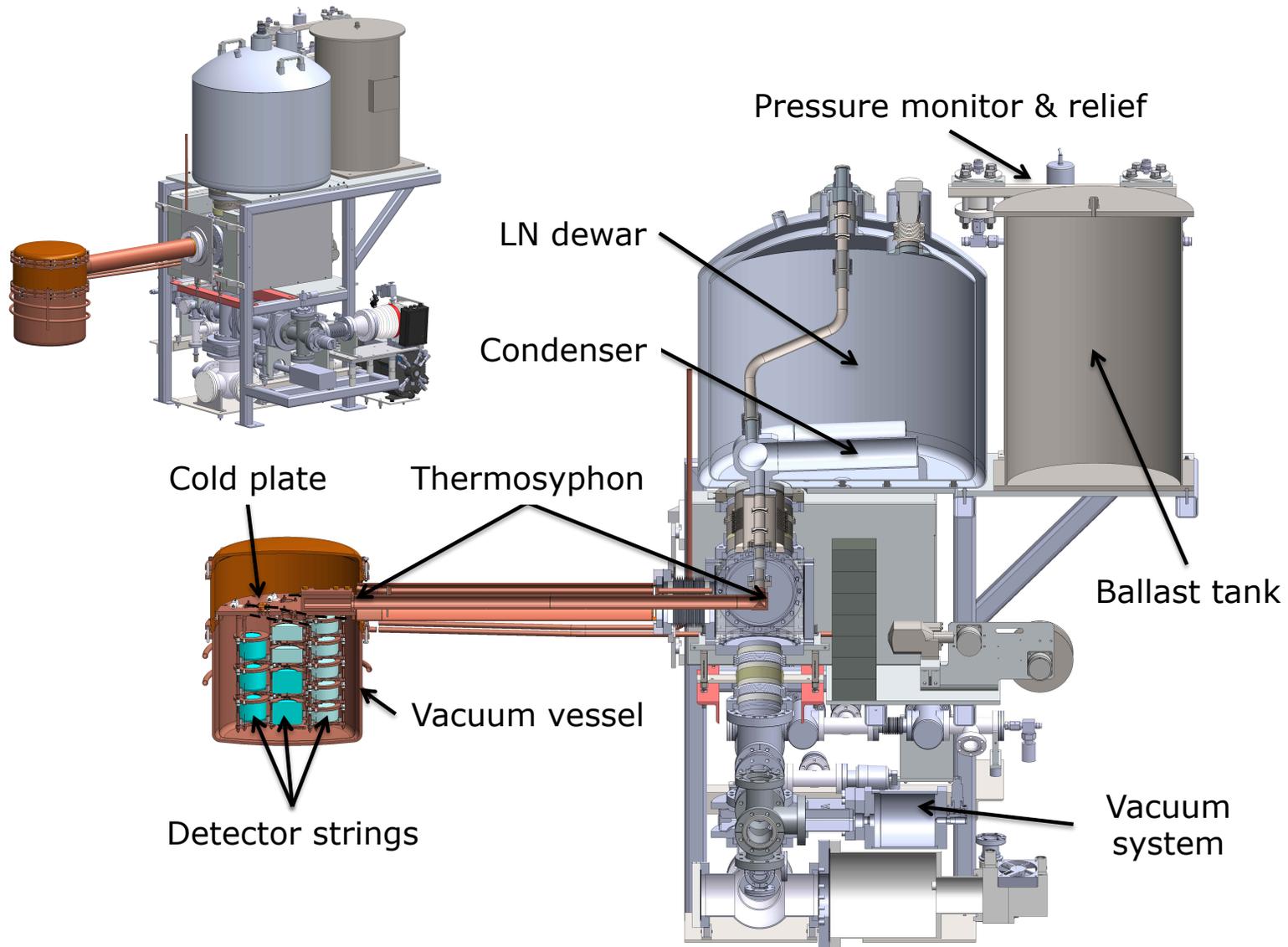


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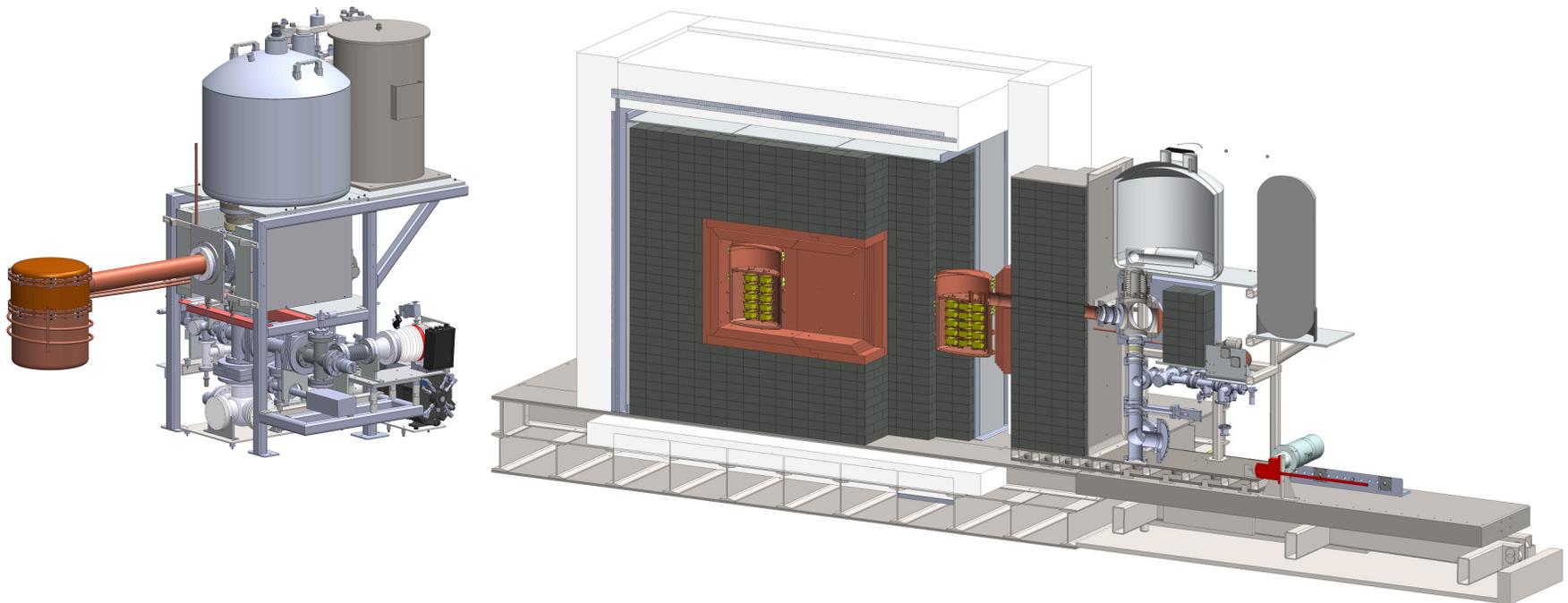
# DEMONSTRATOR Modules



# MJD Module Deployment



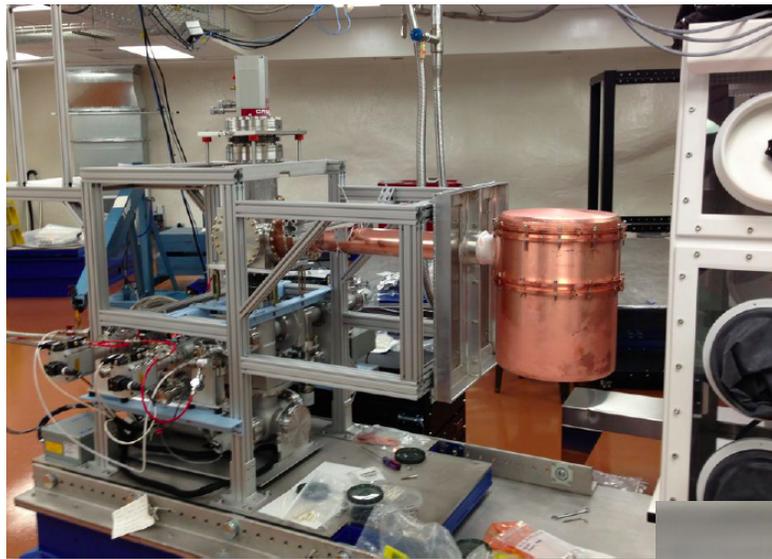
- Prototype Cryostat (2 strings,  $^{nat}\text{Ge}$ ) (NOW)
- Cryostat 1 (3 strings  $^{enr}\text{Ge}$  & 4 strings  $^{nat}\text{Ge}$ ) (Early 2014)
- Cryostat 2 (up to 7 strings  $^{enr}\text{Ge}$ ) (Late 2014)



# MJD Prototype Module



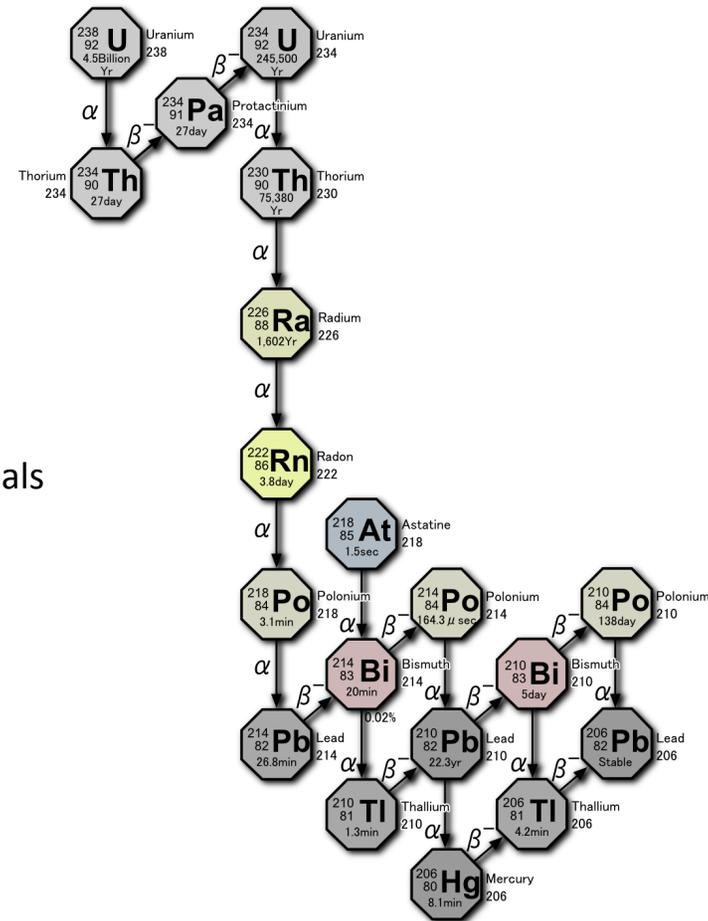
- Commercial Copper Cryostat
- Testbed for MJD:
  - mechanical systems
  - fabrication processes
  - assembly procedures
- Vacuum and cryogenic systems operational
- Have loaded a first string of detectors
- Providing valuable information in preparation for Cryo 1 deployment



# Background Considerations



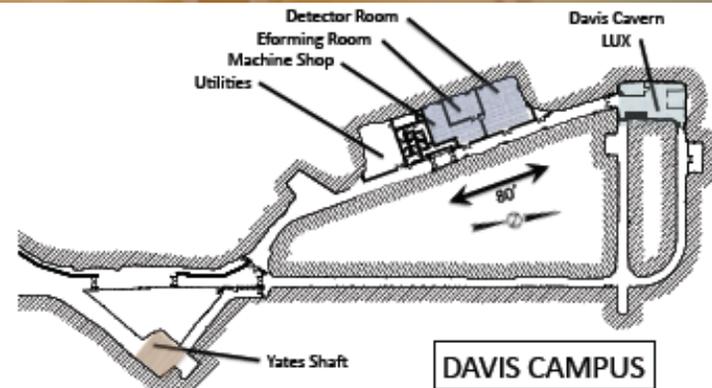
- Cosmic rays
  - Underground deployment
  - Active veto systems
- Radioactive contamination
  - Inherent bulk contamination
    - Materials assay and qualification
    - Pulse Shape Analysis / Granularity cuts
  - Cosmogenic activation
    - Underground storage of sensitive materials
    - Underground materials processing
    - Single-Site Time Correlated event cut
  - Surface contamination
    - Clean-handling processes
- Cavern background
  - Passive shielding



# Underground Deployment



- Sanford Underground Research Facility, Homestake Mine, Lead, SD
- 4850' depth - ~4260 m.w.e. overburden
- Cleanroom lab environment (<500 particles/ft<sup>3</sup>)



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# Radiopure Materials



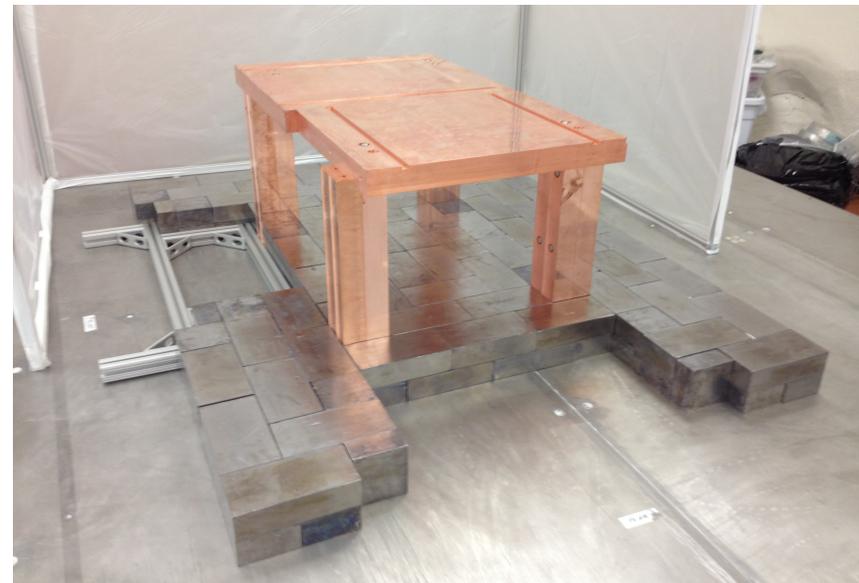
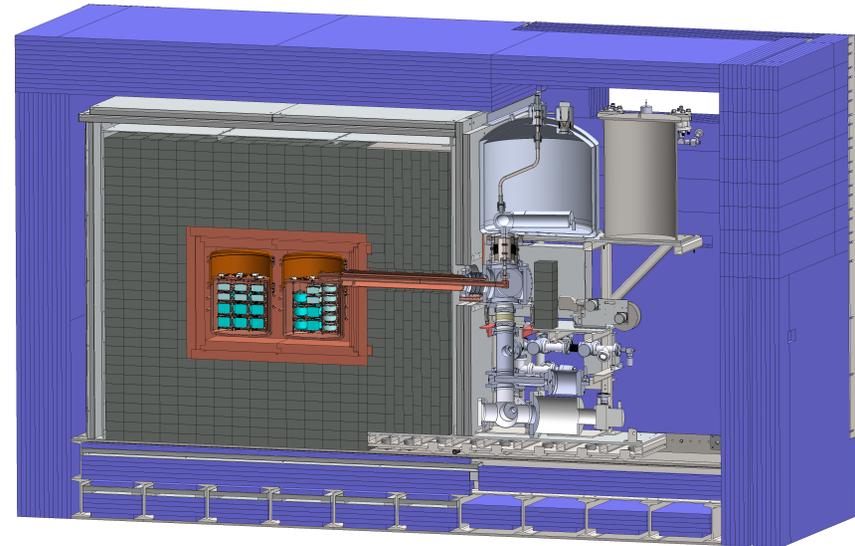
- Extensive campaigns to qualify, procure, produce clean materials
  - NAA, ICPMS,  $\gamma$ -counting used for material assay
  - Ultra-pure electroformed copper, produced underground for detector components, cryostats, shielding
  - High-purity PTFE insulators
- UG manufacturing for reduction of cosmogenic activation
  - Fully-outfitted machine shop
  - Chemistry lab for cleaning and surface treatment



# Passive Shielding: Copper, Lead, Poly



- 5cm ultra-pure EFCu inner shield
- 5cm low-background commercial copper outer shield
- 45cm stacked lead
- 30cm HDPE, inner 5cm borated
- Inner shield EFCu in production
- Outer copper shield fabrication, assembly in progress
- Lead procured, cleaned, stacking begun
- HDPE panels on-site and in fabrication



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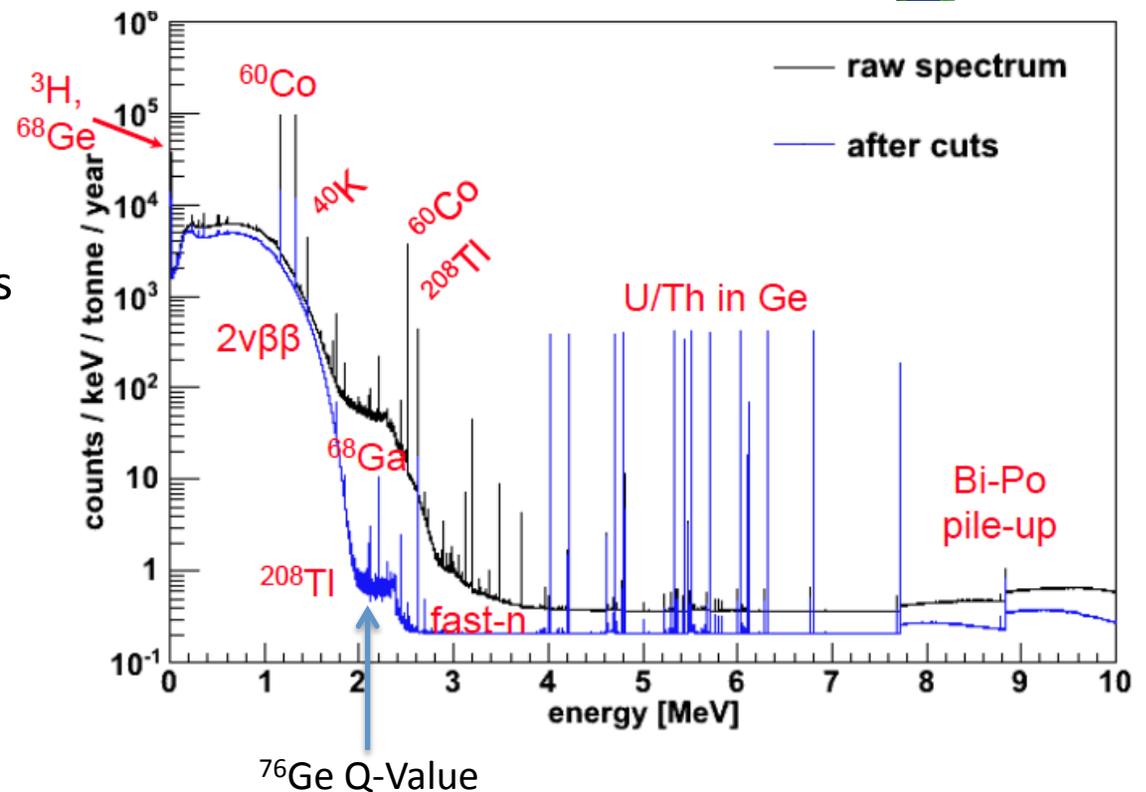
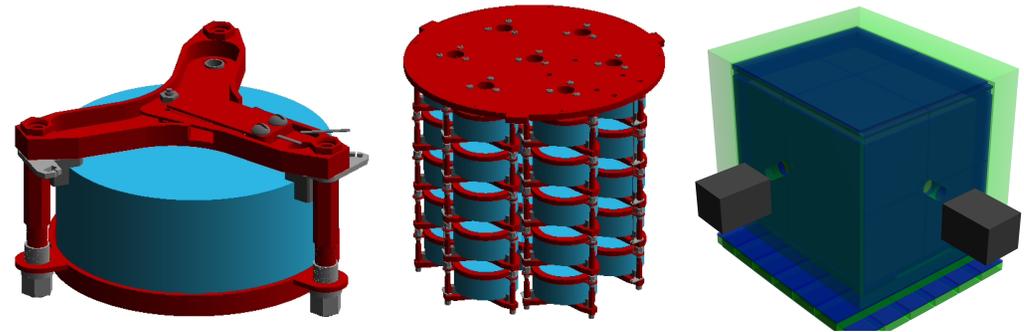
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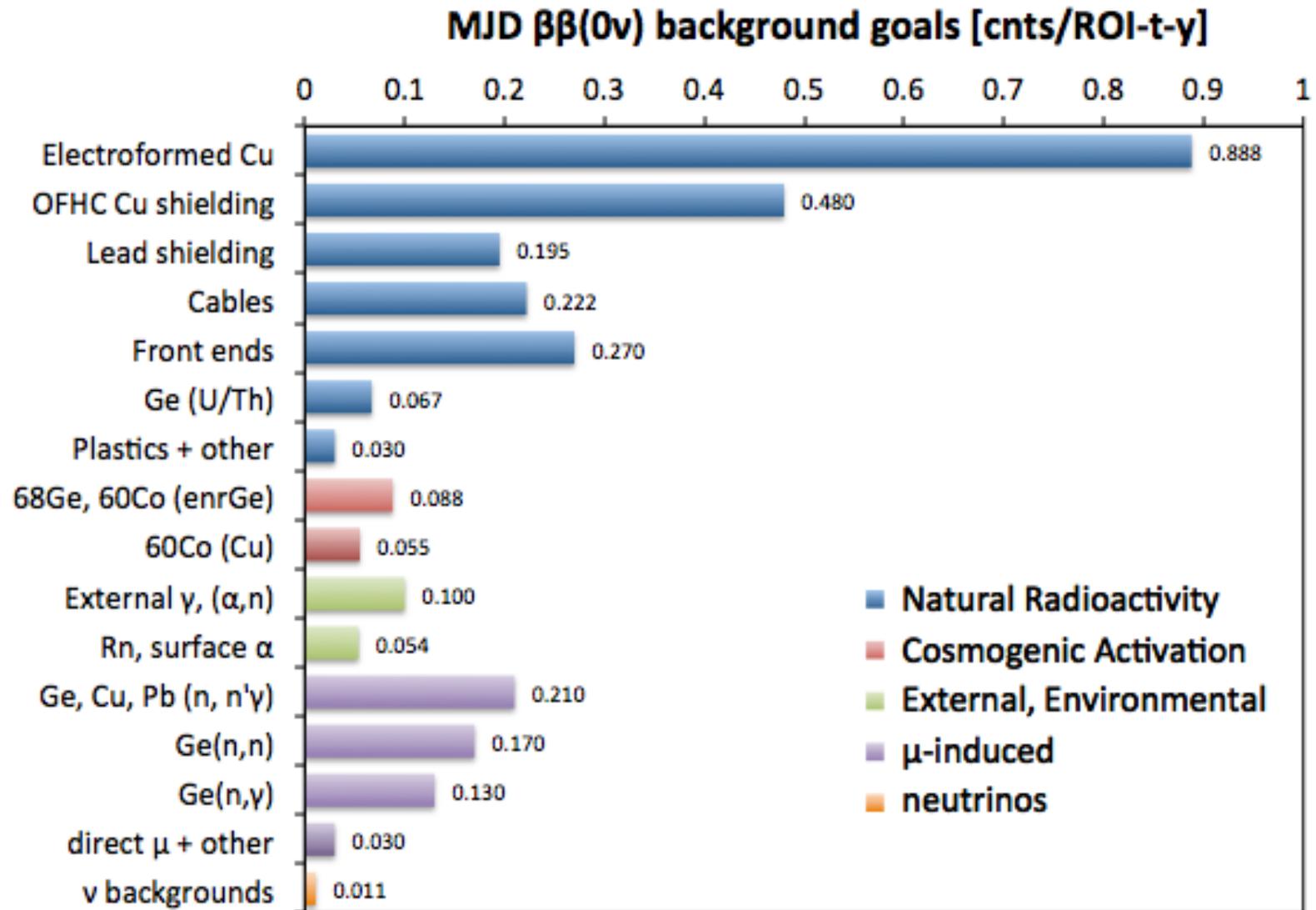
# Geant4/MaGe Background Simulations



- Full-spectrum background model:
  - Uranium / Thorium decay chains
  - $^{40}\text{K}$  /  $^{60}\text{Co}$  /  $^{68}\text{Ge}$
  - $\alpha$  /  $\beta$  emitting surface contaminants
  - Neutron backgrounds
- Engineering design support
  - Shielding / veto efficiencies
  - Materials qualifications
  - Calibration system design
- Estimation of effectiveness of analysis cuts
- $\sim 60\text{k}$  CPU hrs, 15Tb data on NERSC clusters



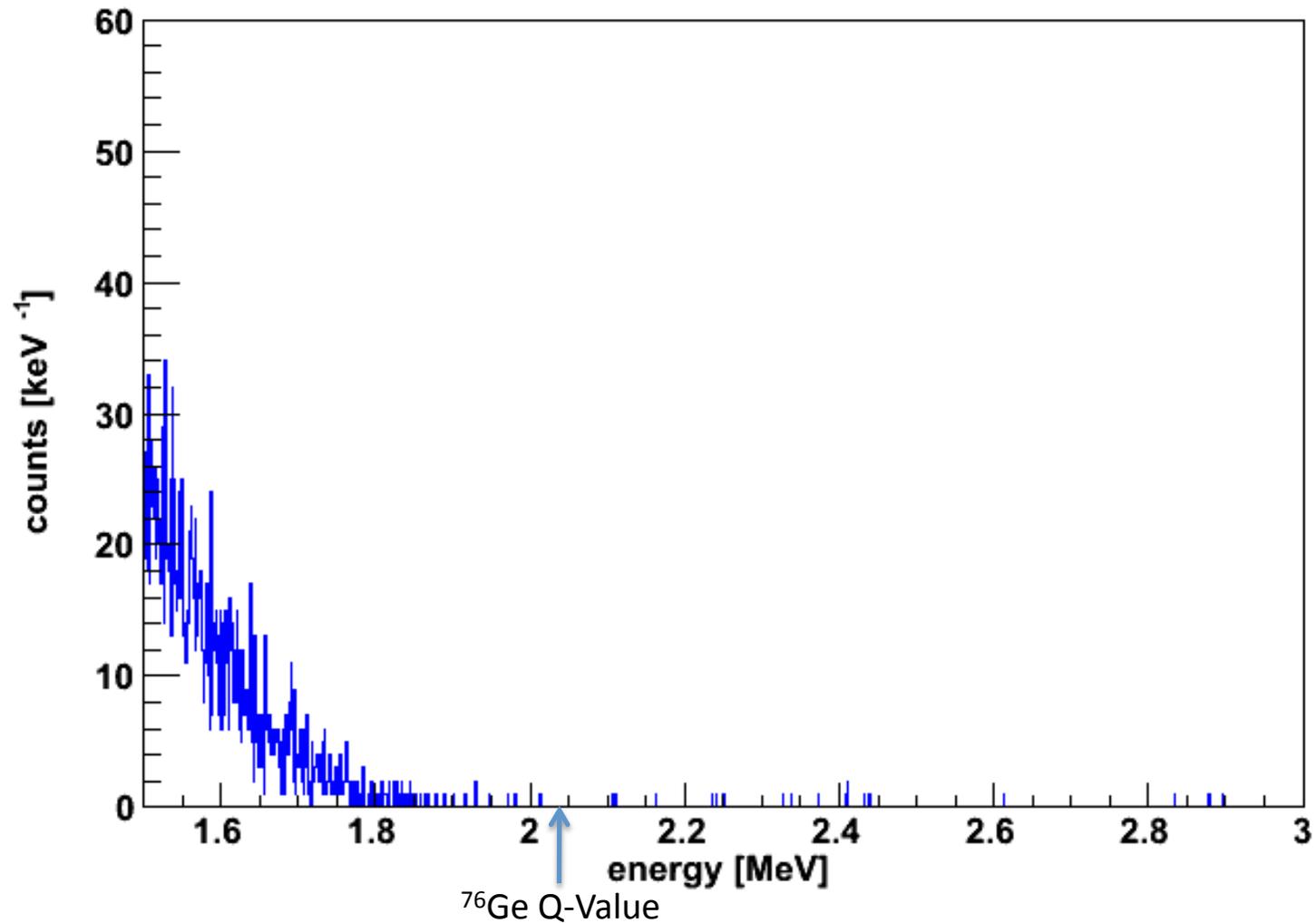
# MJD Background Budget



# MJD Simulated Spectrum: ~3years



Simulated spectra, 60 kg yrs, detector resolution + all cuts applied



# Beyond Double-beta Decay

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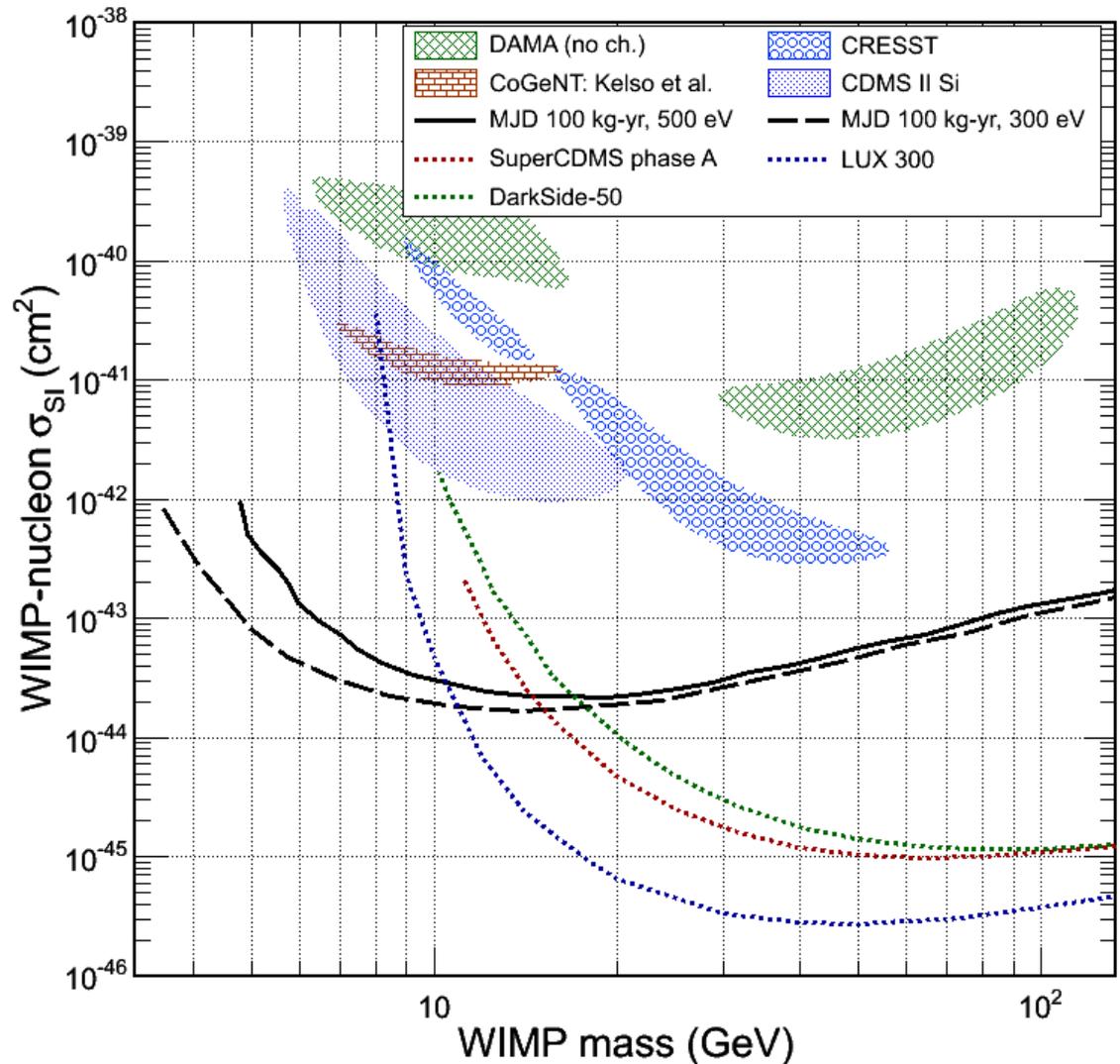


- The DEMONSTRATOR is a unique ultra-low background, low-threshold, high-resolution detector; possible searches for new physics include:
  - Dark Matter WIMPs
  - Axions
  - Sterile neutrinos
  - Other exotic physics
- The technology developed for use in the DEMONSTRATOR has other applications
  - Homeland security
  - Medical imaging
  - Coherent, elastic neutrino–nucleus scattering

# MJD Dark Matter Sensitivity



- Popular Dark Matter candidate: Weakly Interacting Massive Particles (WIMPs)
- Low threshold allows sensitivity to low-mass WIMPs
- PPC detectors provide a unique opportunity to probe an open region of WIMP detection space!
- Establishing low energy threshold and low backgrounds key to this effort



# MAJORANA DEMONSTRATOR Summary



- Construction of MJD well underway and proceeding rapidly!
  - Prototype Cryostat : Now
  - Cryostat 1 : Early 2014
  - Cryostat 2 : Late 2014
- Working cooperatively with GERDA towards the establishment of a single international  $^{76}\text{Ge}$   $0\nu\beta\beta$  collaboration



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# The MAJORANA Collaboration



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**Anne-Marie Suriano**, Jared Thompson

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## *University of Alberta, Edmonton, Alberta*

Aksel Hallin

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Reyco Henning, Mark Howe, Sean MacMullin, **Benjamin Shanks**,  
Christopher O'Shaughnessy, **Jacqueline Strain**, **Kris Vorren**, John F. Wilkerson

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## *University of South Dakota, Vermillion, South Dakota*

**Nathan Snyder**

## *University of Tennessee, Knoxville, Tennessee*

Yuri Efremenko, Sergey Vasilyev

## *University of Washington, Seattle, Washington*

Tom Burritt, Clara Cuesta, Jason Detwiler, Peter J. Doe, **Julietta Gruszko**, Greg Harper,  
**Jonathan Leon**, David Peterson, R. G. Hamish Robertson, Alexis Schubert, Tim Van Wechel

# Other MJD Presentations @TAUP!

---



- Giovanetti, Graham: *A Dark Matter Search with The MAJORANA Low-Background Broad Energy Germanium Detector*, Dark Matter I Parallel Session
- Abgrall, Nicolas: *The MAJORANA Low-Background, Low-Noise, Front-End Electronics*, Poster DBD-28
- Cuesta Clara: *The MAJORANA DEMONSTRATOR*, Poster YR-23
- Goett, John: *The MAJORANA DEMONSTRATOR Calibration System*, Poster DBD-32
- Henning, Reyco: *Physics Beyond Neutrinoless Double-Beta Decay with a Tonne-Scale Germanium Experiment*, Poster DBD-27
- Xu, Wenqin: *Characterization of the Ge Detectors for the MAJORANA DEMONSTRATOR*, Poster DBD-22, YR-3